Driver Alertness Monitoring Systems in Commercial Trucks

Project by the Driver Alert Designers (DAD):
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PACCAR

Problem

11.8% of crashes involve one large truck [1]
- 8 out of 10 people in these crashes killed

Average truck driver sleeps 4.78 hours before 10-13 hr shift [2]
- About half reported experiencing at least one 6-min drowsy period

Economic Impact:
~$13,033,724 saved each year in U.S. with installation of driver alert system in PACCAR trucks

Goal

1. **Determine optimal camera location**
   - Captures all 36 eye points
2. **Minimize driver obstruction of view**
3. **Evaluate best feedback system**
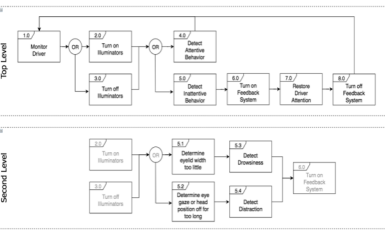   - Intuitive not intrusive

Figure 1: System's Functional Diagram

Literature Review

- Common ways truck drivers stay alert:
  - Cooling the cab, listening to the radio, drinking coffee, stretching, talking to the CB radio, eating, smoking, or singing. [3]
- Inattention becomes distraction in the presence of a critical incident. [4]
- Frequent or demanding activities pose higher risks. [5]
- Most common head pose angles of truck drivers:
  - ± 90° yaw, ± 45° pitch, and ± 20° roll. [7]

CAD Modeling

To determine camera locations that would capture all 36 eye points, the camera and its field of view was modeled in CAD and placed at 6 feasible locations. The model did not show scenarios in which the nose or hair covered a driver's eye, thus the physical installation and experimentation helped to validate and determine our final location.

Figure 2: (left) CAD model with mannequin, eyepoints, and camera FOV.
Figure 3: (right) Final locations of the 4 cameras used for testing.

Simulation

A truck simulator was used to test the different camera placements and warning systems. While all four cameras recorded, drivers were asked to perform a series of tasks, such as:
- Looking at different areas of the cab
- Answering and dialing a number using a cellphone
- Wiping the steering wheel and dashboard
- Reading a piece of paper taken from their pocket

Drivers were then exposed to different warning systems and asked to evaluate them.

Figure 4: The Kenworth truck simulator by MiniSim, located at the PACCAR Advanced Research Center at the University of Washington

Feedback System

Auditory Warnings: "Eyes on the road" → Progresses as distracted behavior increases → "Alert, Alert"

Visual Warnings: → Progresses as distracted behavior increases →

Combination Warnings: → Progresses as distracted behavior increases →
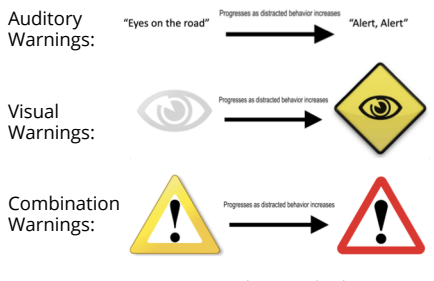
Figure 5: Messages and icons used in the warnings

Participant Survey

Participants filled out surveys giving their opinions on the feedback systems, camera locations, and alertness monitoring system.

2. Cameras
a. On a scale of 1 to 5, with 1 being not at all and 5 being very much so, how much did the locations of the cameras obstruct your view? Circle your answer below.

Camera 1:	1	2	3	4	5
Camera 2:	1	2	3	4	5
Camera 3:	1	2	3	4	5
Camera 4:	1	2	3	4	5

b. If it were up to you, where would you like the camera to be? It does not have to be one of the given locations and you can suggest multiple locations.

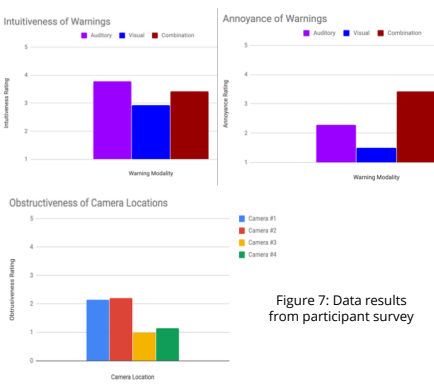Figure 6: Sample questions used in the participant survey

Figure 7: Data results from participant survey

Results

14 participants with varying attributes including:
- Gender
- Truck Drivers (CDL)
- Bespectacled
- Height

This created a more accurate representation of the demographics of truck drivers.

Figure 7: Participant Demographics

Figure 8: Camera Location Video Results (% Time)

Category 1: one eye missing
- Best: Cameras 1 & 2
  - <1% time eyes missing
- Worst: Camera 4
  - Due to nose blocking left eye

Category 2: both eyes missing
- Best: Camera 4
  - Due to angle of camera
- Worst: Camera 3
  - Due to movement from given tasks
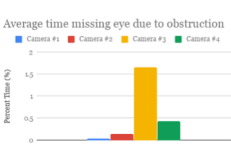
Category 3: eyes obstructed
- Best: Cameras 1 & 2
- Worst: Camera 3
  - Due to brim of glasses or arms reaching above

Recommendations

Camera locations: 1 and 2
- They capture the eyes the most & deliver better fields of view that constantly span the driver's eyes.
- Participants rated both locations as more obstructive but with marginal difference to the other two.

Feedback System: Auditory
- Auditory warnings → most intuitive
- Visual warnings → least annoying
  - Truck drivers, however, found visual warnings highly annoying.

References:
[1]"Large Trucks and Buses by the Numbers", Federal Motor Carrier Safety Administration, 2019, [Online]. Available: https://www.fmcsa.dot.gov/ourroads/large-trucks-and-buses-numbers. [Accessed: 26- May- 2019]. [2] Miller, M., Miller, J., Lipsitz, J., Walsh, J. and Wylie, D. (1998). The Sleep of Long-Haul Truck Drivers. New England Journal of Medicine, [online] 338(6), pp.389-391. Available at: https://www.nejm.org/doi/full/10.1056/NEJM199802053380606?URL=ver=Z39 [3] United States. Federal Highway Administration. Office of Motor Carrier Research Standards, Decision Research, & Essex Corporation. (1999). Commercial truck driver fatigue, alertness, and countermeasures survey. (Techbrief). Washington, DC]: Federal Highway Administration, Office of Motor Carriers, Office of Motor Carrier Research and Standards. [4] Hanowski, R., Perez, M. and Dingus, T. (2005). Driver distraction of long-haul truck drivers. Transportation Research Part F: Traffic Psychology and Behaviour, [online] 8(6), pp.441-458. Available at: https://www.sciencedirect.com/science/article/pii/S1369847805000586 [5] Grace, R., Byrne, V., Bierman, D., Legrand, J., Gricourt, D., Davis, R., Staszewski, J. and Carnahan, B. (1998). A Drowsy Driver Detection System for Heavy Vehicles. Digital Avionics Systems Conference, [online] Vol.2. Available at: https://ieeexplore.ieee.org/abstract/document/585491 [6] Parmonte, D.P. (2012). U.S. truck driver anthropometric study and multivariate anthropometric models for cab designs. Human factors, 54(5), 849-71. Available at: https://www.ncbi.nlm.nih.gov/pubmed/23156627 [7] D. Walger, T. P. Breckon, A. Gaszczak and T. Popham. (2014). A comparison of features for regression-based driver head pose estimation under varying illumination conditions. 2014 International Workshop on Computational Intelligence for Multimedia Understanding (IWCIM), pp. 1-5. Available at: https://ieeexplore.ieee.org/document/7008805